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INVESTIGATIONS LEADING TO THE DEVELOPMENT
OF A PRIMARY ZINC-SILVER OXIDE BATTERY
OF IMPROVED PERFORMANCE CHARACTERISTICS

1 January 1965 - 31 March 1965

Contract No. NAS-8-5493

Control No. TP3-83728

CPB 13-1600-63

George C. Marshall Space Flight Center
Huntsville, Alabama

I. PURPOSE

The immediate objective during this extended contract period shall be the design of a zinc-silver oxide cell capable of activated stand periods and recharge abilities as follows:

A. Stand period (for useful life) - thirty days
B. Stand temperature - 90° F
C. Cycle capability - six cycles in thirty days
   1. Five cycles removing 25% depth
   2. A final discharge of 100% capacity
D. Battery voltage during discharge - 28 ± 2.0 volts
   (1.40 ± 0.10 volts per cell)

Related studies will be carried out as required to achieve this goal.

II. ABSTRACT

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Considerable effort has been expended in studies directed at discovering a procedure resulting in optimum utilization of positive active materials. This has been done primarily by studying the electroformation process associated with the silver plate. Under experimental conditions, procedures have been described whereby sintered silver plates consistently display oxygen content indicating more than 95% of the divalent capacity.

Other studies described include the following:

A) Effect of Silver-Zinc Ratio
B) Electrolyte Additives
C) Effects of Cell Tightness and Quantity of Electrolyte.

Author

III. FACTUAL DATA AND DISCUSSION

A. General

Progress during the past quarter has related primarily to two broad phases of study which were carried on simultaneously--positive plate studies and full-cell investigations.

B. Positive Plate Studies (Electroformation)

1. Purpose

The object of these investigations was the improvement of the electroformation process, in terms of the quantity of oxygen added to the silver material during the process. It was specifically desired to determine the combination of silver apparent density (in gm/in^3) and charge input which would result in the greatest possible utilization of the silver positive plate.

2. Procedure

In all formation studies positive plates 2 7/8" x 6" were used. These were of the sintered silver type, with the active material being pressed upon silver grid of 4/0 mesh. A doubled silver wire of 0.030" diameter was attached to each plate and served as current lead wire. Plates were compressed individually to the thickness required for the desired apparent density. The charge input, in per cent of theoretical was based upon that required for complete conversion to the divalent state. Plates were charged in individual cell cases against inert electrodes. Potassium hydroxide solution of 1.300 specific gravity was used as the electrolyte in each instance.

a. Second Fractional Factorial Experiment

1) Plan

The previously quarterly report described the difficulty with which plates of apparent densities of 90-110 gm/in^3 were formed. It was, therefore, decided to investigate decreased densities of the range of 70-90 gm/in^3 and charge inputs of 120 to 323% of theoretical. Factors and levels were designated as follows:

FACTOR	LEVEL					
	0	1	2	3	4	5
Silver Density	70	75	80	85	90	95
% Charge	120	156	171	218	254	323

A fractional factorial experiment was again employed, following a modified plan of Addelman ("Orthogonal Main-Effect Plans", Addelman-Kempthorne, Plan No. 7). This plan utilized eighteen trials, which are summarized in Table No. 1. Plates were charged at 0.88 amperes per square inch of superficial surface area for the period of time designated by the plan. The gain in weight of each plate during the electroformation process was again used as the response for that trial. A response of 14.8% corresponds to complete conversion of metallic silver to the divalent state.

2) Discussion of Data

Table No. 1 lists responses obtained for each of eighteen trials. Also listed are the mean (x) values of the responses for the three plates tested at each silver density level. These values have been utilized in the analysis of variance, the data for which appear in Table Nos. 5 and 6. In order to best estimate the significance of effects, data were treated by (1) analysis of variance and (2) simple comparison of means. This is true for the "electroformation" process as well as for the "discharge efficiency" phase in which the discharge capacity of the formed plates was determined.

a) Analysis of Variance(Charge Efficiency)

Table Nos. 2 and 3 contain responses as arranged for analysis of the effect of silver apparent density and charge input, respectively. The detailed computation is indicated at the bottom of each of the above tables. Each of these analyses required the calculation of a "correction factor", "total sum of squares", for the effect being analyzed. These values are summarized in Table No. 4, a summary of the Analysis of Variance. The total degrees of freedom, (df), were 17, since there were eighteen trials. Each effect investigated has 5 degrees of freedom, since there were six levels of each effect involved. Therefore, the residual (error) degrees of freedom are seven, by difference. The corrected sum of squares for each effect was divided by the number of degrees of freedom to obtain a "mean square" value for each. Each mean squares value was then divided by the residual (error) mean squares figure to yield the "F test" value. These F test values, when compared to those appearing in Davies' "Design and Analysis of Industrial Experiments", yielded the significance values indicated. Both effects were judged significant - that of change input to the 0.05 level, and that of silver density at the 0.005 level. The preferred silver density was found to be 70 gm/in^3, as this density exhibited a high mean value and a low variance. Charge input analysis was not so clear-cut, the indication being that an input of 156% was preferred (on the basis of a low magnitude of variability). Analysis of variance for main effects may be misleading in the presence of interactions.

b) Analysis by Comparisons of Means (Charge Efficiency)

Additional analysis by simple comparison of means, which is often sufficient in itself, was also performed. Table No. 7 lists the arrangement of the responses for this analysis for silver density, while Table No. 8 indicates the arrangement of the responses for the analysis of charge input.

A summary of pertinent data is as follows:

	Density	Mean Response ($\bar{x}$)	Overall Mean ($\bar{x}$)
1.	70 gm/in^3	13.28%	11.01%

Formation at a silver density of 70 yielded a gain of 2.27 percentage units over the overall mean.

	Density	Mean Response ($\bar{x}$)	Overall Mean ($\bar{x}$)
2.	75 gm/in^3	12.00%	11.01%

Formation at a silver density of 75 yielded a gain of 0.99 percentage units over the overall mean.

3. $80\ gm/in^3$ 10.91% 11.01%
Formation at a silver density of 80 yielded a loss of 0.10 percentage units from the overall mean.

4. $85\ gm/in^3$ 10.62% 11.01%
Loss of 0.39 percentage units from the overall mean.

5. $90\ gm/in^3$ 10.00% 11.01%
Loss of 1.01 percentage units from the overall mean.

6. $95\ gm/in^3$ 9.25% 11.01%
Formation at a silver density of 95 yielded a weight increase 1.76 percentage units below the overall mean.

On the basis of simple examination of means, the lowest silver density investigated is to be preferred.

Similarly, comparison of means with respect to the effect of charge input is as follows:

% Charge	Mean Response ($\bar{x}$)	Overall Mean ($\bar{X}$)	($\bar{X} - \bar{x}$)
1. 120%	11.59%	11.01%	+1.58%
2. 156%	11.33%	11.01%	+0.32%
3. 171%	12.04%	11.01%	+1.03%
4. 218%	11.00%	11.01%	-0.01%
5. 254%	10.56%	11.01%	-0.45%
6. 323%	9.74%	11.01%	-1.27%

The above analysis indicated that a charge input of 171% of theoretical produced the greatest percentage weight increase, on the average. The single trial producing the greatest percentage weight increase, however, was the combination of 70 gm/in^3 density and 120% of theoretical charge input. This was a weight increase of 14.36%, which is 3.35 percentage units above the overall mean.

b) Third Factorial Experiment

The above experimental series confirmed that the most desirable silver apparent density range lies below 85 gm/in^3. It was also indicated that little or no additional oxygen was added to plates by increasing the charge input above 170% of that required for complete conversion to the divalent state. This study, therefore, involved the use of silver plates of three densities: 70, 75, and 80 grams per cubic inch. Three levels of charge input, 120%, 140%, and 160% were also studied. As indicated by Table No. 9, each of the nine possible combinations was duplicated, giving a total of eighteen trials. Table No. 10 lists specific weight data and repeats response data.

Table Nos. 11-15 list calculations used in evaluating the data by means of Analysis of Variance, including estimations of the significance of the variables, density and charge input. As indicated by Table No. 11, the effects of both density and charge input upon the variability of the process were pronounced, even over the reduced spread of variable levels under investigation.

Table No. 14 reveals that the mean response of all plates having densities of 70 gm/in^3 was 13.52%, as compared to 11.67 and 12.03 for densities of 75 and 80 gm/in^3, respectively. Table No. 15 indicates that those plates receiving 140% of the charge theoretically required for the conversion of all silver to the divalent state achieved the greatest average weight gain, 13.60%, as compared to 12.43 and 12.54 for those receiving 120% and 160% charge inputs, respectively.

Inspection of these data indicates, therefore, that the greatest oxygen weight gain would be otained under the following conditions: 1) silver apparent density no greater than 75 gm/in^3 and probably nearer 70 gm/in^3; and, 2) a charge input of approximately 140% of that theoretically required for complete conversion to the divalent state.

c) Fourth Factorial Experiment

1. Purpose

The object of this latest full factorial experiment was to determine whether interrupted charging would increase the charge effectiveness of plates of higher density.

2. Procedure

Six levels of silver density, ranging from 73 to 98 $grams/inch^3$, were selected for study. "Soak" times, during which the plate was allowed to remain in the electrolyte, ranged from zero to twelve hours. Table No. 16 contains a complete description of the test plan. As in previously described experiments, plates were charged between inert electrodes in 1.300 specific gravity potassium. All plates were charged initially 150% of their theoretical capacity, after which the prescribed soak time was allowed. Following the soak, an additional 50% of the theoretical capacity was passed through the plates.

3. Results and Discussion

Table No. 17 contains the responses, which are expressed as the per cent weight gain of the silver plates.

Table Nos. 18 and 19 contain the Analysis of Variance of the experiment with respect to the effect of silver apparent density and soak time, respectively. This analysis required the calculations indicated with each individual table. A summary of the Analysis of Variance appears in Table No. 20. Table Nos. 21 and 22 list the mean responses achieved at each level of the two factors, as well as the variance displayed for each level. It is indicated again that lower densities result in greater weight gains. This, as discussed in previous reports, is consistent with other results and well verified at this point. The benefits of the interruption in charge, however, is less certain. The greatest responses were those associated with a "soak" of eight hours. The mean response for these treatments was 12.61% as compared to 11.70% for a soak of four hours and 12.17% for a soak of twelve hours. It appears that some novel approach may be required to produce any significant improvement in formation of plates of higher density.

C. Full Cell Studies

1. Ratio of Materials Study

a) Purpose

This study was intended to reveal the effect of positive-to-negative active material ratio upon capacity retention over a period of one month.

b) Procedure

Cells were constructed with seven positive plates and eight negative plates, each 1 5/8" x 2". This cell displays a mean full capacity of approximately fourteen ampere-hours when discharged at a thirty ampere rate to an end voltage of 1.30 volts per cell. Three ratios of positive to negative material were used. These were 1.08:1, 1.15:1 and 1.26:1 for Series I, Series II and Series III, respectively.

All cells were activated with 20cc of 1.400 specific gravity potassium hydroxide electrolyte and discharged at thirty amperes to 1.30 volts per cell to determine initial capacities. Cells were then recharged fully and subjected to five cycles of 25% depth during a period of one month. At the end of this period, cells were again discharged fully as described above. Table Nos. 23-25 list all test data obtained from these cells.

c) Results

The following table summarizes the results of this study.

TABLE NO. 22-A
RATIO OF MATERIALS STUDY

Series	Ratio Ag:Zn	Ci (A.H.)	Cf (A.H.)
I	1.08:1	13.55	14.1
II	1.15:1	14.5	13.9
III	1.26:1	14.65	12.7

NOTE: C_i indicates initial mean capacity
C_f indicates mean capacity following thirty days of cycle testing.

It is evident that the initial capacity was greater for those cells having the largest amount of silver, while after thirty days activated life, with the cycle history listed by Table Nos. 23-25, those cells having the most zinc and least silver displayed greatest capacity. This is an indication that the capacity degeneration of the zinc plate proceeds more rapidly than the loss from the positive group. Therefore, cells tend to be negative-limited following thirty days activated life. Interpolation of these data indicate that a silver-zinc ratio 1.11:1.00 might yield, under these specific discharge conditions, a relatively stable capacity over the useful life of the cell.

2. Electrolyte Additive Study

a. Purpose

The object of this study was to determine whether any of several electrolyte additives might result in significant benefits in capacity retention over a period of thirty days.

b. Procedure

The following solutions of additives in 1.400 specific gravity potassium hydroxide electrolyte were prepared by The Eagle-Picher Analytical Laboratory:

(a) Kaolin (20% saturated, 80% saturated)
(b) Polyethylene Oxide (20% saturated, 80% saturated)
(c) Lithium Hydroxide (20% saturated, 80% saturated)
(d) Aluminum Hydroxide (20% saturated, 80% saturated)
(e) Elvanol (PVA), (20% saturated, 80% saturated)
(f) $Na_x(SiO_2)_y$ (1 wt. %, 10 wt. %)

Cells of the same size and nominal capacity as used previously were activated with twenty cc of the appropriate electrolyte. Certain cells were discharged to 1.30 end voltage on the initial cycle to establish full capacity. Others were discharged for 7.5 minutes at 30 amperes, or approximately 25% of full depth. Results of this and other cycles are included in Table No. 27, Table No. 26 specifies the electrolyte employed in each cell.

c. Results and Conclusions

The only obvious significant effects were those caused by deleterious additives. For instance, both concentrations of $Na_x(SiO_2)_y$ resulted in poor discharge voltage. The greater concentration of this additive resulted in complete disability of cells to reach acceptable discharge voltage at a 30 ampere rate, following 30 days activated life. Discharge capabilities of cells using the higher concentration of lithium hydroxide similarly failed to discharge satisfactorily, while the lower concentration revealed no apparently significant effect. The mean capacity of all cells except those described above was 12.5 ampere-hours. The mean capacity of cells having no electrolyte additive was also 12.6 ampere-hours. This appears coincidental, as the six cells having aluminum hydroxide additive displayed an average capacity of 13.3 ampere-hours, while the remaining cells with additives (polyethylene oxide, kaolin and elvanol) exhibited an average capacity of 12.10 ampere-hours. It is indicated, therefore, that for this particular regime of testing, the addition of aluminum hydroxide might be beneficial.

TABLE NO. 26

ELECTROLYTE ADDITIVES

CELL NUMBERS	ADDITIVES
1-10	None
11,12	Polyethylene Oxide (20% sat.)
13,14	Polyethylene Oxide (80% sat.)
15,16	Kaolin (20% sat.)
17,18	Kaolin (80% sat.)
19-21	LiOH (20% sat.)
22-24	LiOH (80% sat.)
31-33	Al_2O_3 (20% sat.)
34-36	Al_2O_3 (80% sat.)
37-39	Elvanol (20% sat.)
40-42	Elvanol (80% sat.)
43-45	$Na_x(SiO_2)_y$, 1% by wt.
46-48	$Na_x(SiO_2)_y$, 10% by wt.
49-51	None

The mean capacity of all cells except those described above was 12.6 ampere hours. The mean capacity of cells having no electrolyte additive was also 12.6 ampere hours. This appears coincidental, as the six cells having aluminum hydroxide additive displayed an average capacity of 13.3 ampere hours, while the remaining cells with additives, (polyethylene oxide, kaolin, and elvanol) exhibited an average capacity of 12.10 ampere hours. It is indicated, therefore, that for this particular regime of testing, the addition of aluminum hydroxide might be beneficial.

3. Effect of Cell Tightness and Quantity of Electrolyte

a. Purpose

The object of this phase of study is to determine whether certain combinations of cell tightness and quantity of electrolyte result in improvement in voltage regulation or capacity retention.

b. Procedure

Cells used in this series were similar to those described above with respect to active material weights and type of separator system. In all cells, the separator system consisted of non-woven nylon fabric, two wraps of cellophane and non-woven rayon. Shims of two thicknesses were used to provide the variable of tightness. Electrolyte volumes of 19, 19.5 and 20 cc's were selected. All possible combinations of these variables were employed as indicated by Table No. 28.

c. Results and Conclusions

Table No. 29 displays cycle data for these cells. Unless indicated by a capacity value, each cycle was of 25% depth. Although cycling of these cells has not been completed, preliminary results indicate that no degradation in performance has been caused by increasing the cell pack through the addition of shims of up to 0.020" thickness. It is also indicated that reduction of the quantity of electrolyte to 19.5 cc without affecting cell capacity is possible. Following completion of cycle testing, the experimental data will be more thoroughly analyzed.

TABLE NO. 28

EFFECT OF CELL TIGHTNESS AND QUANTITY OF ELECTROLYTE

CELL NUMBERS	VOLUME OF ELECTROLYTE	SHIM THICKNESS
1-7	19.0	------
8-14	19.5	------
15-20	20.0	------
21-27	19.0	0.010"
28-34	19.5	0.010"
35-40	20.0	0.010"
41-47	19.0	0.020"
48-54	19.5	0.020"
55-60	20.0	0.020"

IV. RESULTS AND CONCLUSIONS

A. Positive Plate Studies

An extensive series of studies has been directed at evaluating the formation process of the positive plate. Particular emphasis was placed upon measuring the completion of the formation process for various combinations of plate "apparent density" and charge input. This was accomplished by determining the weight of oxygen added to the silver sinter during the electroformation process. A percentage increase of 14.83% would be indicative of complete conversion of silver to the divalent state.

Early tests confirmed the difficulty in charging very dense or compact plates. For instance, initial studies revealed a mean response of 13.28% for plates of 70 gm/in^2, compared to only 9.25% for plates of 95 gm/in^3. Individual trials at the lower density levels ranged up to 14.36% or more than 96% of theoretical. It was concluded that under conditions of constant current charging the optimum state of charge may be achieved through the following conditions:

1) Silver apparent density no greater than 75 gm/in^2 and probably nearer 70 gm/in^2.

2) A charge input approximately 140% that theoretically required for complete conversion to the divalent state.

Conditions of intermittent charge have been studied briefly, with no substantial improvement in oxygen addition.

B. Ratio of Materials Studies

Test cells of 13-15 ampere capacity have been cycle tested to determine effects of the silver-zinc ratio upon capacity characteristics. Ratios of 1.08:1, 1.15:1 and 1.26:1 were investigated. It was found that the greater numerical ratios resulted in greater initial capacity, indicating positive capacity limitation. Decreased numerical ratios, however, resulted in greater capacity after completion of cycle testing of one month duration. It is estimated that a compromise ratio of approximately 1.11:1 might result in relatively stable capacity over the useful cell life. (A discharge rate of thirty amperes is normal for all full-cell cycle studies).

C. Electrolyte Additive Studies

A number of electrolyte additives have been evaluated in cells of similar capacity to those discussed above. The only obvious significant effects were those caused by deleterious additives, for instance sodium silicate. Possible beneficial effects were associated with aluminum hydroxide additives. At termination of testing, cells employing this additive displayed 13.3 ampere-hours capacity, compared to 12.1 ampere hours for all cells with no additives or additives which caused no obvious effect.

D. Effect of Cell Tightness and Quantity of Electrolyte

The combined effects of cell group tightness and electrolyte quantity are being evaluated by cycle testing a number of cells employing various combinations of these variables. Cycling of these cells has not been completed, but preliminary results indicate no degradation in performance has been caused by reducing the quantity of electrolyte by 0.5-1.0 cubic centimeter or by increasing the cell group tightness by 0.020." The latter is equivalent to increasing slightly the quantity of active material in the cell. Both measures represent possible slight increases in the cell energy density.

V. PERSONNEL

The following number of man-hours have been expended during the contract period:

Engineering:	4596
Technical:	7447
Total	12,043

APPENDIX

Table No. 1
Silver Plate Formation Study
Second Factorial Experiment

Trial	Silver Density Level	Per cent Charge Level	Response (% weight increase)
1	0	0	14.36
2	0	2	13.49
3	0	4	11.99
4	1	1	13.31
5	1	3	12.75
6	1	5	9.94
7	2	0	11.35
8	2	2	11.99
9	2	4	9.39
10	3	1	11.29
11	3	3	10.63
12	3	5	9.95
13	4	0	9.05
14	4	2	10.64
15	4	4	10.30
16	5	1	8.80
17	5	3	9.62
18	5	5	9.33

Table No. 1A
Silver Plate Formation Study
Second Factorial Experiment

Responses-% Weight Gain

Trial	Final Ag. Wt.	Initial Ag Wt.	Weight Gain	% Gain	Mean
1	145.08	126.86	18.22	14.36	
2	146.98	129.51	17.47	13.49	13.28
3	146.26	130.60	15.66	11.99	
4	149.36	131.82	17.54	13.31	
5	145.01	128.61	16.40	12.75	12.00
6	144.24	131.20	13.04	9.94	
7	137.22	123.23	13.99	11.35	
8	149.42	133.42	16.00	11.99	10.91
9	143.88	131.53	12.35	9.39	
10	147.42	132.46	14.96	11.29	
11	143.12	130.13	13.83	10.63	10.62
12	143.56	130.57	12.99	9.95	
13	139.20	127.65	11.55	9.05	
14	144.26	130.39	13.87	10.64	10.00
15	143.61	130.20	13.41	10.30	
16	138.03	126.86	11.17	8.80	
17	141.45	129.04	12.41	9.62	9.25
18	144.31	132.00	12.31	9.33	

Overall Mean	11.01

% Wt. Gain = (Wt. gain/Initial Wt.) x 100

Table No. 2
Silver Plate Formation Study
Second Factorial Experiment
Analysis of Variance
(Silver Density)

Ag Density (gm/in^3)	70	75	80	85	90	95	Total
Response	14.36	13.31	11.35	11.29	9.05	8.00	68.15
	13.49	12.75	11.99	10.63	10.64	9.62	69.12
	11.99	9.94	9.39	9.95	10.30	9.33	60.90
$\sum x_i$	39.84	36.00	32.73	31.87	29.99	27.75	198.18
$\bar{x}$	13.28	12.00	10.91	10.62	10.00	9.25	

$\sum (x_i^2) = 2228.92$

Correction Factor $= (198.18)^2/18$
$= 2181.96$

Total Sum of Squares $= \sum (x_i^2) - C.F.$
$= 46.95$

Density S of S $= (39.84^2 + \ldots + (27.75^2)/3 - C.F.$
$= 36.25$

Table No. 3
Silver Plate Formation Study
Second Factorial Experiment
Analysis of Variance
(percent charge)

% Charge	120	156	171	218	254	323	Total
Response	14.36	13.31	13.49	12.75	11.99	9.94	75.84
	11.35	11.29	11.99	10.63	9.39	9.95	64.60
	9.95	8.80	10.64	9.62	10.30	9.33	57.74
Σx_1	34.76	33.40	36.12	33.00	31.68	29.22	198.18
$\bar{x}$	11.59	11.13	12.04	11.00	10.56	9.74	

$\Sigma (x_i^2) = 2228.02$

Correction Factor = 2181.96

Total Sum of Squares = 46.96

% Charge S of S = $(34.76^2 = \ldots + 29.22^2)/3$ - C. F.
= 9.67

Table No. 4
Silver Plate Formation Study
Second Factorial Experiment
Summary, Analysis of Variance

Source	df	Corrected S of S	M. S.	F	Signif.
Total	17	46.96	---	--	-----
Ag Dens.	5	31.25	6.25	7.27	0.005
% Chg.	5	9.67	1.93	2.24	0.05
Resid.	7	6.04	0.86	--	---

df = degrees of freedom

F = variance ratio

From Davies' "Design and Analysis of Industrial Experiments" :

F must exceed 3.20 for 0.005 Significance

F must exceed 2.10 for 0.05 Significance

Table No. 5
Silver Plate Formation Study
Second Factorial Experiment

Silver Density	Variance $\Sigma X_i^2 - (\Sigma X_i)^2/9$	Response mean
70 gm/in^3	2.88	13.28
75	6.52	12.00
80	3.68	10.91
85	0.90	10.62
90	1.40	10.00
95	0.34	9.28

Table No. 6
Silver Plate Formation Study
Second Factorial Experiment
Calculation of Variance

% charge	Variance	Response mean
120%	14.18	11.59
156%	11.08	11.13
171%	4.07	12.04
218%	5.10	11.00
254%	3.48	10.56
323%	0.26	9.74

Table No. 7
Silver Plate Formation Study
Analysis by Comparison of Means

Ag Density	70	75	80	85	90	95 gm/in^3
% gain	14.36	13.31	11.35	11.29	9.05	8.80
	13.49	12.75	11.99	10.63	10.64	9.62
	11.99	9.94	9.37	9.95	10.30	9.33
Σx	39.84	36.00	20.73	31.87	29.99	27.75
$\bar{x}$	13.28	12.00	10.91	10.62	10.00	9.25

Overall mean = 11.01

Table No. 8
Silver Plate Formation Study
Analysis by Comparison of Means

% Charge	120	156	171	218	254	323
	14.36	13.31	13.47	12.75	11.99	9.94
% gain	11.35	11.29	11.99	10.63	9.39	9.95
	9.05	8.80	10.64	9.62	10.30	9.33
Σx	34.76	33.40	36.12	33.00	31.68	29.22
$\bar{x}$	11.59	11.33	12.04	11.00	10.56	9.92

Overall mean = 11.07

TABLE NO. 9
SILVER PLATE FORMATION STUDY (L_{1-9} & H_{1-9})
THIRD FACTORIAL EXPERIMENT

	Trial	Silver Density	Percent Charge	Response % Gain
1	L-1	71	120	12.97
2	2	70	140	14.15
3	3	70	160	12.28
4	4	76	120	13.07
5	5	75	140	14.03
6	6	75	160	13.28
7	7	80	120	12.28
8	8	79	140	12.33
9	9	80	160	12.48
10	H-1	68	120	13.40
11	2	68	140	14.57
12	3	68	160	13.76
13	4	75	120	12.16
14	5	74	140	13.98
15	6	75	160	11.67
16	7	82	120	10.70
17	8	79	140	12.54
18	9	80	160	11.82

NOTE: The original plan called for densities of 70, 75, and 80 gm/in^3. Certain small individual deviations from this plan occurred as indicated by the appropriate column above.

TABLE NO. 10
SILVER PLATE FORMATION STUDY
THIRD FACTORIAL EXPERIMENT
RESPONSES - PERCENT WEIGHT GAIN

Trial	Final Silver Weight	Initial Silver Weight	Weight Gain	Percent Gain
L-1	131.90	116.76	15.14	12.97
2	131.44	115.15	16.29	14.15
3	131.18	116.83	14.35	12.28
4	137.10	121.25	15.85	13.07
5	134.50	117.95	16.55	14.03
6	130.90	115.55	15.35	13.28
7	129.41	115.26	14.15	12.28
8	132.45	117.91	14.54	12.33
9	144.24	128.24	16.00	12.48
H-1	142.09	125.30	16.79	13.40
2	142.75	124.60	18.15	14.57
3	142.93	125.64	17.29	13.76
4	141.90	126.52	15.38	12.16
5	145.01	127.22	17.79	13.98
6	141.96	127.12	14.84	11.67
7	137.73	124.42	13.31	10.70
8	142.58	126.69	15.89	12.54
9	145.52	130.14	15.38	11.82

TABLE NO. 11
SILVER PLATE FORMATION STUDY
THIRD FACTORIAL EXPERIMENT
ANALYSIS OF VARIANCE
(Arranged by Silver Density)

Ag Density	L 70	M 75	H 80	Total
% Weight Gain	12.97	13.07	12.28	38.32
% Weight Gain	14.15	14.03	12.33	40.51
% Weight Gain	12.28	13.28	12.48	38.04
% Weight Gain	13.40	12.16	10.70	36.26
% Weight Gain	14.57	13.98	12.54	41.09
% Weight Gain	13.76	11.67	11.82	37.25
ΣXi	81.13	78.19	72.15	231.47
$\bar{X}$	13.52	13.03	12.03	
$(\Sigma Xi)^2$	1100.42	1023.52	870.03	2994.11

$$\text{Correction Factor} = (231.49)^2 \div 18$$

$$= 53578.36 \div 18$$

$$= 2976.58$$

$$\text{Total Sum of Squares} = (\text{Total, each response})^2 - CF$$

$$= 2994.11 - 2976.58$$

$$= 17.53$$

$$\text{Density Sum of Squares} = \frac{(81.19)^2 + (78.19)^2 + (72.20)^2}{6} - 2976.58$$

$$= \frac{17902.10}{6} - 2976.58$$

$$= 2983.68 - 2976.58$$

$$= 7.10$$

TABLE NO. 12
SILVER PLATE FORMATION STUDY
THIRD FACTORIAL EXPERIMENT
Analysis of Variance (Percent Charge)

% Charge	L 120	M 140	H 160	Total
% Gain	12.97	14.15	12.28	39.40
% Gain	13.07	14.03	13.28	40.38
% Gain	12.28	12.33	12.48	37.09
% Gain	13.40	14.57	13.76	41.73
% Gain	12.16	13.98	11.67	37.81
% Gain	10.70	12.54	11.82	35.06
Σ Xi	74.58	81.60	75.29	231.47
$\bar{X}$	12.43	13.60	12.54	
$(\Sigma Xi)^2$	931.76	1114.07	948.15	2994.11

$$\text{Correction Factor} = (231.47)^2 \div 18$$

$$= 53578.36 \div 18$$

$$= 2976.58$$

$$\text{Total Sum of Squares} = (\text{Total, each response})^2 - CF$$

$$= 2994.11 - 2976.58$$

$$= 17.53$$

$$\%\text{ of Charge Sum of Squares} = (74.58)^2 + (81.60)^2 + (75.29)^2 - CF$$

$$= \frac{17889.3205}{6} - 2976.58$$

$$= 2981.55 - 2976.58$$

$$= 4.97$$

TABLE NO.13
SILVER PLATE FORMATION STUDY
THIRD FACTORIAL EXPERIMENT
SUMMARY, ANALYSIS OF VARIANCE

Source	df	Corrected Sum Of Squares	Mean Square	F	*Significance
Total	17	17.53	----	----	-----
Silver Density	2	7.10	3.55	8.45	0.005
% Charge	2	4.97	2.49	5.93	0.005
Residual	13	5.46	0.42	----	-----

df = Degrees of freedom; F = Variance ratio

*Davies' "Design and Analysis of Industrial Experiments"

F value must exceed 3.20 for 0.005 significance.

TABLE NO. 14
SILVER PLATE FORMATION STUDY
THIRD FACTORIAL EXPERIMENT
CALCULATIONS OF VARIANCE FOR EACH
SILVER DENSITY

$$\text{Variance} = \Sigma X_i - \frac{(X_i)^2}{n}$$

$$\text{Varinace, Density 70} = 1100.42 - \frac{6582.08}{6}$$

$$= 1100.42 - 1097.01$$

$$= 3.41 \; ; \; \bar{X} = 13.52$$

$$\text{Variance, Density 75} = 1023.52 - \frac{6113.68}{6}$$

$$= 1023.52 - 1018.95$$

$$= 4.57 \; ; \; \bar{X} = 11.67$$

$$\text{Variance, Density 80} = 870.03 - \frac{5205.62}{6}$$

$$= 870.03 - 867.60$$

$$= 2.43 \; ; \; \bar{X} = 12.03$$

TABLE NO. 15
SILVER PLATE FORMATION STUDY
THIRD FACTORIAL EXPERIMENT
CALCULATIONS OF VARIANCE FOR EACH
PERCENT OF CHARGE

$$\text{Variance} = \Sigma X_i^2 - \frac{(\Sigma X_i)^2}{n}$$

$$\text{Variance, 120\% Charge} = 931.76 - \frac{\overset{(74.58)^2}{(5562.18)}}{6}$$

$$= 931.76 - 927.03$$

$$= 4.73;\ \bar{X} = 12.43$$

$$\text{Variance, 140\% Charge} = 1114.07 - \frac{(81.60)^2}{6}$$

$$= 1114.07 - \frac{6658.66}{6} = 1114.07 - 1109.76$$

$$= 4.31\ ;\ \bar{X} = 13.60$$

$$\text{Variance, 160\% Charge} = 948.12 - \frac{(75.29)^2}{6}$$

$$= 948.15 - \frac{(75.29)^2}{6}$$

$$= 948.15 - \frac{5668.58}{6}$$

$$= 948.15 - 944.76$$

$$= 3.39\ ;\ \bar{X} = 12.54$$

TABLE NO. 16

SILVER PLATE FORMATION STUDY
Fourth Factorial Experiment

Factors and Levels

Trial	Silver Density	Gm/In^3	Soak Time	Hours
S-1	0	73	0	4
S-2	0	73	1	8
S-3	0	73	2	12
S-4	1	78	0	4
S-5	1	78	1	8
S-6	1	78	2	12
S-7	2	83	0	4
S-8	2	83	1	8
S-9	2	83	2	12
S-10	3	88	0	4
S-11	3	88	1	8
S-12	3	88	2	12
S-13	4	93	0	4
S-14	4	93	1	8
S-15	4	93	2	12
S-16	5	98	0	4
S-17	5	98	1	8
S-18	5	98	2	12

TABLE NO.17

SILVER PLATE FORMATION EXPERIMENT

Responses - Percent Weight Gain

Trial	Final Ag Weight	Initial Ag Weight	Weight Gain	Percent Gain	$\bar{x}$
S-1	140.74 gm	124.00 gm	16.74	13.50	
S-2	134.56	117.82	16.74	14.20	14.06
S-3	134.30	117.30	17.00	14.49	
S-4	133.97	119.45	14.52	12.16	
S-5	133.75	118.00	15.75	13.35	12.70
S-6	144.12	128.00	16.12	12.59	
S-7	134.60	120.21	14.39	11.97	
S-8	131.84	116.40	15.44	13.26	12.84
S-9	142.75	126.00	16.75	13.29	
S-10	132.92	119.00	13.92	11.70	
S-11	140.45	125.00	15.45	12.36	12.05
S-12	134.50	120.00	14.50	12.08	
S-13	139.74	127.00	12.74	10.03	
S-14	140.40	125.0	15.40	12.32	10.87
S-15	131.77	119.0	12.27	10.31	
S-16	137.40	124.0	13.40	10.81	
S-17	133.31	121.0	12.31	10.17	10.41
S-18	138.90	126.0	12.90	10.24	

TABLE NO. 18

SILVER PLATE FORMATION STUDY
Fourth Factorial Experiment

Analysis of Variance - Silver Density

Ag Density	73	78	83	88	93	98	Total
Response	13.50	12.16	11.97	11.70	10.03	10.81	70.17
Response	14.20	13.35	13.26	12.36	12.32	10.17	75.66
Response	14.49	12.59	13.29	12.08	10.31	10.24	73.00
Σxi	42.19	38.10	38.52	36.14	32.66	31.22	218.83
$\bar{x}$	14.06	12.70	12.84	12.05	10.87	10.41	
$\Sigma(xi)^2$	593.85	484.60	495.73	435.59	358.68	325.14	2693.59

Correction Factor = $(218.83)^2/18$

= 2660.36

Total Sum of Squares = (Total, each response) - C.F.

= (2693.59) - (2660.36)

= 33.23

Density S of S = $1/3\ (42.19)^2 + \ldots\ (31.22)^2$ - C.F.

= 27.26

TABLE NO. 19

SILVER PLATE FORMATION STUDY
Fourth Factorial Experiment

Analysis of Variance - Soak Time

Soak Time (Hours)	4	8	12	Total
Response	13.50	14.20	14.49	42.19
Response	12.16	13.35	12.59	38.10
Response	11.97	13.26	13.29	38.52
Response	11.70	12.36	12.00	36.14
Response	10.03	12.32	10.31	32.66
Response	10.81	10.17	10.24	31.22
Σ xi	70.17	75.66	73.00	218.83
$\bar{x}$	11.70	12.61	12.17	
$\Sigma(\ xi)^2$	827.74	963.67	902.17	2693.59

Correction Factor = $(218.83)^2/18$

= 2660.36

Total S of S = Total $\Sigma(\ xi)^2$ - C.F.

= 2693.59 - 2660.36

= 33.23

Soak Time S of S = $((70.17)^2 + (75.66)^2 + (73.00)^2)/6$ - C.F.

= 2.51

TABLE NO. 20

SILVER PLATE FORMATION STUDY
Fourth Factorial Experiment

Summary, Analysis of Variance

Source	df	Corrected S of S	Mean Squares	F	Significance*
Total	17	33.23	----	-----	-----
Silver Density	5	27.26	5.45	15.57	0.005
Soak Time	2	2.51	1.76	5.03	0.005
Residual	10	3.46	0.35	-----	-----

df = Degrees of freedom

F = Variance Ratio

* Davies: Design and Analysis of Industrial Experiments

F must exceed 3.20 for 0.005 significance

TABLE NO.21

SILVER PLATE FORMATION STUDY
Fourth Factorial Experiment

Calculation of Variance for Each Silver Density

Density	Mean Response	Variance
73 gm/in^3	14.06	0.53
78 gm/in^3	12.70	0.73
83 gm/in^3	12.84	1.13
88 gm/in^3	12.05	0.22
93 gm/in^3	10.87	3.12
98 gm/in^3	10.41	0.24

$$\text{Variance} = \Sigma(xi^2) - (\Sigma xi)^2/n$$

TABLE NO.22

SILVER PLATE FORMATION STUDY
Fourth Factorial Experiment

Calculation of Variance for Each Soak Time

Soak Time	Mean Response	Variance
4 Hours	11.70	7.10
8 Hours	12.61	9.60
12 Hours	12.17	14.00

$$\text{Variance} = \Sigma x_i^2 - (\Sigma x_i)^2/n$$

TABLE NO. 23
RATIO OF MATERIALS STUDY
GROUP III

Cycle		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17*	18*
1	Vi	1.37	1.39	1.35	1.36	1.36	1.36	1.36	1.36	1.38	1.40	1.42	1.40	1.40	1.40	1.39	1.40		
	V max	1.44	1.45	1.43	1.45	1.45	1.46	1.46	1.46	1.44	1.45	1.46	1.46	1.46	1.46	1.46	1.45		
	Cap. (AH)	12.8	13.5	13.8	13.8	13.5	14.3	14.0	13.3	13.0	11.5	12.5	14.3	14.5	13.8	14.5	13.8		
2	V_i	1.39	1.40	1.40	1.41	1.33	1.41	1.40	1.40	1.40	1.41	1.40	1.40	1.39	1.39	1.38	1.38	1.38	1.30
	V max	1.41	1.42	1.43	1.43	1.38	1.43	1.43	1.43	1.43	1.44	1.43	1.43	1.43	1.43	1.44	1.44	1.44	1.40
3	Vi	1.38	1.37	1.37	1.37	1.36	1.37	1.38	1.38	1.38	1.37	1.36	1.36	1.37	1.37	1.34	1.36	1.36	1.32
	V max	1.43	1.43	1.43	1.43	1.43	1.43	1.44	1.44	1.44	1.43	1.44	1.43	1.44	1.44	1.42	1.44	1.43	1.43
4	Vi	1.40	1.39	1.40	1.41	1.41	1.38	1.40	1.39	1.39	1.40	1.40	1.38	1.38	1.39	1.38	1.38	1.37	**
	V max	1.43	1.43	1.43	1.43	1.43	1.42	1.42	1.44	1.43	1.43	1.43	1.43	1.43	1.44	1.44	1.45	1.43	
5	Vi	1.33	1.34	1.34	1.35	1.35	1.33	1.35	1.35	1.35	1.35	1.35	1.35	1.35	1.35	1.33	1.34	1.34	
	V max	1.38	1.39	1.39	1.40	1.39	1.40	1.40	1.39	1.39	1.38	1.40	1.40	1.40	1.40	1.39	1.39	1.39	
6	Vi	1.36	1.37	1.37	1.37	1.37	1.36	1.37	1.37	1.37	1.37	1.35	1.36	1.36	1.36	1.35	1.36	1.35	
	V max	1.40	1.41	1.42	1.41	1.41	1.41	1.41	1.41	1.41	1.40	1.41	1.41	1.41	1.41	1.40	1.41	1.39	
7	Vi	1.40	1.39	1.42	1.41	1.42	1.39	1.40	1.40	1.43	1.39	1.40	1.40	1.41	1.40	1.39	1.39	1.40	
	V max	1.42	1.41	1.43	1.42	1.42	1.42	1.42	1.42	1.43	1.41	1.43	1.43	1.43	1.42	1.42	1.43	1.42	
	Cap. (AH)	14.3	13.8	14.5	14.5	14.0	14.0	13.8	14.3	14.3	12.5	14.5	14.3	14.0	14.5	14.5	14.5	14.0	

* Indicates discharge rate other than thirty amperes

** Denotes cell failure

V_i indicates discharge voltage after thirty seconds discharge

Vmax indicates maximum voltage attained during discharge

TABLE NO.24
RATIO OF MATERIALS STUDY
GROUP IV

CYCLE		CELL NUMBER 1	2	3*	4*	5	6	7	8	9	10*	11	12	13	14	15	16	17	18	19	20*	21*
1	Vi	1.40	1.37			1.34	1.36	1.32	1.35	1.36		1.35	1.36	1.38	1.38	1.37	1.36	1.35	1.36	1.36		
	V max	1.44	1.44			1.41	1.42	1.41	1.42	1.42		1.41	1.41	1.43	1.43	1.43	1.43	1.44	1.43	1.42		
	C. (AH)	13.5	14.3			14.0	14.3	15.8	15.3	15.0		14.5	13.5	14.5	15.0	15.0	14.8	14.3	14.0	14.8		
2	Vi	1.39	1.38	1.39	1.40	1.41	1.39	1.37	1.37	1.39		1.37	1.41	1.38	1.39	1.36	1.39	1.38	1.39	1.39	1.38	1.37
	V max	1.41	1.41	1.42	1.43	1.43	1.42	1.42	1.41	1.42		1.42	1.40	1.43	1.42	1.43	1.42	1.43	1.42	1.43	1.43	1.42
3	Vi	1.37	1.35	1.30	1.35	1.36	1.34	1.31	1.33	1.37		1.35	1.31	1.35	1.37	1.37	1.30	1.37	1.33	1.36	1.35	1.28
	V max	1.42	1.41	1.38	1.43	1.43	1.44	1.42	1.43	1.44		1.43	1.41	1.42	1.44	1.44	1.39	1.43	1.41	1.43	1.42	1.41
4	Vi	1.38	1.40	1.39	1.40	1.40	1.38	1.36	1.37	1.39		1.39	1.39	1.39	1.37	1.39	1.38	1.37	1.39	1.38	1.38	1.37
	Vmax	1.42	1.44	1.45	1.45	1.44	1.44	1.43	1.43	1.43		1.44	1.44	1.44	1.44	1.44	1.44	1.44	1.44	1.45	1.44	1.44
5	Vi	1.35	1.33	1.35	1.34	1.34	1.34	1.38	1.32	1.31		1.31	1.27	1.33	1.32	1.36	1.39	1.35	1.34	1.34	1.36	1.33
	Vmax	1.40	1.40	1.41	1.40	1.40	1.41	1.38	1.39	1.39		1.39	1.38	1.39	1.38	1.41	1.36	1.40	1.40	1.39	1.40	1.39
6	Vi	1.39	1.36	1.36	1.39	1.37	1.32	1.34	1.37	1.36		1.37	1.36	1.37	1.38	1.38	1.33	1.37	1.36	1.38	1.39	1.36
	Vmax	1.43	1.41	1.44	1.44	1.43	1.41	1.41	1.43	1.42		1.42	1.42	1.42	1.42	1.43	1.42	1.42	1.42	1.43	1.44	1.42
7	Vi	1.36	1.34	1.33	1.32	1.33	1.33	1.30	1.32	1.34		1.34	1.33	1.38	1.37	1.37	1.36	1.37	1.38	1.36	1.37	1.34
	Vmax	1.40	1.40	1.40	1.40	1.39	1.39	1.40	1.40	1.40		1.40	1.42	1.42	1.42	1.42	1.43	1.43	1.43	1.41	1.41	1.40
	C. (AH)	13.5	13.0	13.5	13.5	13.5	14.5	13.5	13.8	14.8		13.8	14.5	13.8	14.0	13.8	13.8	14.0	14.8	14.8	14.8	13.5

* Indicates discharge rate other than thirty amperes.

Vi indicates discharge voltage after thirty seconds discharge

V max indicates maximum voltage attained during discharge

TABLE NO. 25
RATIO OF MATERIALS STUDY
GROUP NO. V

Cycle			Cell Number 1	2	3	4	5	6	7	8	9	10	11	12	13*	14*	15	16
CYCLE	1	Vi	1.36	1.32	1.38	1.34	1.33	1.35	1.35	1.32	1.32	1.36	1.35	1.33			1.32	1.32
		Vmax	1.42	1.41	1.43	1.42	1.45	1.46	1.45	1.45	1.45	1.45	1.45	1.46			1.40	1.41
		C(AH)	12.5	13.5	14.5	12.0	15.5	16.5	15.5	15.5	15.8	13.3	14.5	16.0			14.0	13.5
	2	Vi	1.32	1.37	1.41	1.33	1.36	1.37	1.37	1.36	1.34	1.40	1.38	1.37	1.34	1.36	1.37	1.37
		Vmax	1.38	1.44q	1.44	1.38	1.43	1.43	1.43	1.43	1.43	1.42	1.43	1.43	1.43	1.44	1.45	1.45
	3	Vi	1.30	1.34	1.40	1.17	1.36	1.38	1.37	1.31	1.34	1.38	1.37	1.37	1.36	1.36	1.35	1.35
		Vmax	1.40	1.43	1.44	1.29	1.43	1.44	1.43	1.41	1.43	1.43	1.44	1.44	1.41	1.42	1.40	1.40
	4	Vi	1.31	1.34	1.40	1.32	1.35	1.37	1.36	1.33	1.35	1.36	1.36	1.37	1.35	1.36	1.37	1.36
		Vmax	1.39	1.43	1.42	1.42	1.43	1.44	1.43	1.44	1.42	1.44	1.43	1.44	1.44	1.44	1.44	1.42
	5	Vi	1.29	1.33	1.36	1.31	1.33	1.35	1.37	1.33	1.33	1.35	1.36	1.35	1.32	1.33	1.33	1.33
		Vmax	1.37	1.40	1.41	1.46	1.40	1.42	1.43	1.41	1.40	1.39	1.40	1.42	1.39	1.39	1.39	1.38
	6	Vi	1.34	1.38	1.39	1.37	1.37	1.39	1.38	1.35	1.35	1.39	1.36	1.35	1.35	1.38	1.37	1.37
		Vmax	1.41	1.44	1.44	1.42	1.44	1.44	1.45	1.44	1.43	1.43	1.43	1.45	1.43	1.45	1.44	1.43
	7	Vi	1.33	1.36	1.38	1.35	1.35	1.37	1.37	1.34	1.41	1.42	1.37	1.37	1.36	1.39	1.38	1.39
		Vmax	1.38	1.41	1.41	1.38	1.40	1.42	1.42	1.40	1.41	1.41	1.41	1.42	1.42	1.42	1.42	1.42
		C.(AH)	12.3	13.0	13.0	11.0	12.0	12.5	12.8	12.0	11.3	12.0	12.5	12.5	14.0	14.5	14.0	14.0

* Indicates discharge rate other than thirty amperes.

Vi indicates discharge voltage after thirty seconds discharge

V max indicates maximum voltage attained during discharge

TABLE NO. 26
ELECTROLYTE STUDY
GROUP NO. VII

CYCLE NO.		CELL NUMBER 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	Vi	1.34	1.30	1.31	1.33	1.32	1.32	1.34	1.36	1.34	1.32	1.33	1.33	1.33	1.34	1.33	1.35	1.31	1.32	1.34	1.33	1.31	1.33
	V Max	1.42	1.42	1.40	1.42	1.43	1.41	1.40	1.44	1.39	1.40	1.39	1.42	1.42	1.42	1.41	1.42	1.40	1.40	1.41	1.40	1.41	1.41
	Cap. (AH)	12.0	13.25	10.75	12.0	13.25	11.0	9.0*	11.5*	8.5*	10.0*												
2	Vi	1.38	1.38	1.37	1.37	1.36	1.37	1.42	1.39	1.39	1.30	1.37	1.37	1.36	1.38	1.35	1.37	1.33	1.31	1.37	1.36	1.33	1.34
	V Max	1.40	1.40	1.40	1.41	1.41	1.40	1.42	1.42	1.42	1.40	1.41	1.42	1.42	1.42	1.42	1.42	1.42	1.42	1.42	1.43	1.41	1.41
3	Vi	1.41	1.39	1.38	1.40	1.39	1.40	1.41	1.41	1.41	1.37	1.36	1.37	1.36	1.38	1.34	1.35	1.33	1.33	1.35	1.35	1.34	1.34
	V Max	1.43	1.41	1.41	1.42	1.42	1.41	1.42	1.43	1.43	1.42	1.40	1.41	1.41	1.42	1.42	1.42	1.41	1.42	1.42	1.42	1.40	1.41
4	Vi	1.37	1.37	1.36	1.36	1.33	1.34	1.39	1.37	1.37	1.33	1.36	1.37	1.36	1.36	1.33	1.34	1.33	1.33	1.35	1.30	1.37	1.33
	V Max	1.39	1.38	1.38	1.39	1.38	1.38	1.40	1.40	1.39	1.38	1.38	1.39	1.38	1.40	1.38	1.39	1.38	1.38	1.38	1.37	1.37	1.38
5	Vi	1.39	1.39	1.37	1.39	1.38	1.39	1.42	1.42	1.41	1.37	1.43	1.42	1.41	1.41	1.41	1.43	1.40	1.38	1.39	1.38	1.38	1.38
	V Max	1.41	1.41	1.40	1.42	1.42	1.41	1.43	1.43	1.42	1.41	1.41	1.41	1.41	1.41	1.42	1.43	1.42	1.41	1.40	1.40	1.39	1.40
6	Vi	1.37	1.37	1.34	1.37	1.34	1.37	1.38	1.37	1.37	1.31	1.33	1.35	1.34	1.34	1.34	1.34	1.33	1.32	1.32	1.32	1.34	1.33
	V Max	1.38	1.38	1.37	1.38	1.38	1.38	1.39	1.40	1.38	1.36	1.37	1.35	1.37	1.38	1.38	1.39	1.38	1.38	1.37	1.37	1.37	1.39
7	Vi	1.36	1.37	1.34	1.36	1.35	1.36	1.37	1.37	1.37	1.32	1.34	1.37	1.34	1.34	1.34	1.36	1.33	1.33	1.33	1.31	1.35	1.34
	V Max	1.38	1.38	1.38	1.39	1.39	1.38	1.38	1.39	1.38	1.37	1.38	1.35	1.37	1.37	1.38	1.39	1.37	1.37	1.37	1.35	1.38	**
	Cap. (AH)	13.0	12.5	12.5	12.5	13.0	12.5	13.0	13.5	13.0	12.5	12.0	12.25	12.25	11.5	12.0	12.5	12.0	12.25	11.5	12.5	12.0	

* Indicates discharge rate other than thirty amperes

** Denotes cell failure

Vi indicates discharge voltage after 30 seconds

V Max indicates maximum voltage attained during discharge

(continued next page)

TABLE NO. 26 (Con't)
ELECTROLYTE STUDY
GROUP NO. VII

CYCLE NO.		CELL NUMBER																						
		23	24	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51
1	Vi	1.31	1.31	1.35	1.37	1.33	1.35	1.34	1.33	1.35	1.35	1.35	1.35	1.38	1.37	1.32	1.34	1.31	1.26	1.25	1.25	1.36	1.37	1.35
	V Max	1.39	1.40	1.42	1.43	1.42	1.42	1.42	1.42	1.43	1.42	1.43	1.42	1.43	1.43	1.39	1.39	1.40	1.28	1.30	1.30	1.42	1.43	1.42
2	Vi	1.32	1.32	1.37	1.39	1.37	1.33	1.36	1.31	1.39	1.37	1.39	1.36	1.41	1.40	1.33	1.29	1.28	1.20	1.20	1.17	1.33	1.36	1.35
	V Max	1.41	1.41	1.41	1.43	1.42	1.42	1.42	1.41	1.42	1.43	1.43	1.43	1.42	1.42	1.41	1.40	1.39	1.30	1.32	1.30	1.42	1.42	1.42
3	Vi	1.33	1.32	1.31	1.36	1.36	1.34	1.35	1.29	1.35	1.37	1.38	1.36	1.38	1.38	1.33	1.32	1.28	1.22	1.20	1.17	1.34	1.35	1.33
	V Max	1.41	1.40	1.38	1.42	1.42	1.41	1.41	1.39	1.41	1.42	1.42	1.42	1.42	1.42	1.41	1.40	1.40	1.27	1.28	1.26	1.42	1.42	1.41
4	Vi	1.33	1.35	1.33	1.33	1.34	1.33	1.33	1.28	1.33	1.35	1.35	1.34	1.37	1.38	1.32	1.30	1.28	1.28	1.27	1.26	1.33	1.34	1.32
	V Max	1.38	1.38	1.37	1.39	1.39	1.39	1.38	1.37	1.38	1.39	1.40	1.40	1.38	1.38	1.37	1.37	1.37	1.28	1.29	1.29	1.38	1.39	1.37
5	Vi	1.37	1.37	1.33	1.34	1.33	1.33	1.34	1.35	1.35	1.34	1.36	1.35	1.43	1.42	1.37	1.33	1.32	1.29	1.30	1.28	1.38	1.38	1.37
	V Max	1.40	1.40	1.40	1.41	1.41	1.41	1.40	1.39	1.43	1.40	1.41	1.39	1.43	1.42	1.40	1.39	1.39	1.28	1.30	1.30	1.40	1.41	1.41
6	Vi	1.33	1.33	1.36	1.35	1.35	1.34	1.35	1.30	1.37	1.35	1.38	1.33	1.35	1.34	1.32	1.29	1.29	1.28	1.27	1.25	1.32	1.32	1.32
	V Max	1.39	1.39	1.37	1.38	1.37	1.37	1.36	1.36	1.37	1.38	1.38	1.37	1.37	1.37	1.36	1.36	1.33	1.32	1.27	1.25	1.37	1.38	1.37
7	Vi	1.33	1.33	1.37	1.35	1.36	1.36	1.35	1.31	1.37	1.35	1.39	1.34	1.35	1.34	1.31	1.31	1.31	1.31	1.31	1.31	1.32	1.33	1.33
	V Max	**	**	1.37	1.39	1.38	1.37	1.36	1.38	1.39	1.38	1.39	1.36	1.37	1.37	1.35	1.36	1.36	**	**	**	1.38	1.38	1.37
	Cap.(AH)			13.0	14.5	13.5	13.5	11.0	14.5	14.0	12.0	13.0	11.0	11.5	12.0	11.5	11.5	11.5				11.5	12.5	13.0

** Denotes cell failure

Vi indicates discharge voltage after 30 seconds

V Max indicates maximum voltage attained during discharge

TABLE NO. 27

EFFECT OF CELL TIGHTNESS AND QUANTITY OF ELECTROLYTE

GROUP NO. VI

CELL NUMBER

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Vi	1.36	1.36	1.32	1.37	1.35	1.35	1.37	1.35	1.34	1.35	1.36	1.36	1.36	1.36	1.36	1.37	1.36	1.37	1.34	1.34	1.37	1.34	1.34	1.35	1.35	1.35	1.35	1.36
V Max	1.42	1.42	1.41	1.42	1.42	1.42	1.42	1.42	1.42	1.43	1.41	1.41	1.41	1.42	1.42	1.42	1.42	1.42	1.42	1.42	1.43	1.43	1.41	1.41	1.41	1.41	1.42	1.42
Cap. (AH)	14.5	14.5							15.0	15.75									15.0	13.75	14.5	15.0						
Cap																												
Vi	1.42	1.41	1.39	1.41	1.40	1.39	1.41	1.40	1.41	1.39	1.40	1.40	1.39	1.39	1.39	1.39	1.40	1.40	1.40	1.41	1.41	1.39	1.40	1.40	1.39	1.40	1.40	1.41
V Max	1.44	1.43	1.40	1.41	1.41	1.41	1.42	1.41	1.42	1.42	1.42	1.40	1.41	1.40	1.41	1.40	1.41	1.42	1.43	1.43	1.44	1.40	1.41	1.41	1.41	1.42	1.42	1.43
Vi	1.38	1.37	1.37	1.40	1.39	1.39	1.40	1.39	1.38	1.36	1.38	1.38	1.38	1.38	1.38	1.39	1.37	1.38	1.37	1.39	1.38	1.38	1.37	1.39	1.38	1.38	1.38	1.39
V Max	1.42	1.42	1.37	1.40	1.39	1.39	1.40	1.39	1.42	1.42	1.40	1.39	1.39	1.39	1.39	1.39	1.40	1.40	1.41	1.42	1.42	1.42	1.38	1.39	1.39	1.39	1.40	1.39
Vi	1.37	1.35	1.36	1.38	1.36	1.36	1.38	1.37	1.36	1.35	1.37	1.38	1.38	1.37	1.36	1.38	1.38	1.39	1.36	1.38	1.36	1.35	1.35	1.34	1.36	1.37	1.36	1.37
V Max	1.41	1.41	1.36	1.38	1.37	1.37	1.38	1.38	1.41	1.41	1.38	1.38	1.38	1.37	1.36	1.38	1.39	1.39	1.41	1.42	1.41	1.41	1.36	1.36	1.37	1.37	1.38	1.37
	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56
Vi	1.35	1.33	1.36	1.36	1.36	1.35	1.35	1.35	1.35	1.34	1.33	1.32	1.35	1.32	1.36	1.36	1.35	1.35	1.36	1.36	1.34	1.34	1.36	1.36	1.36	1.37	1.33	1.35
V Max	1.43	1.42	1.41	1.42	1.42	1.42	1.42	1.42	1.42	1.42	1.43	1.43	1.43	1.43	1.41	1.41	1.41	1.41	1.42	1.42	1.42	1.42	1.40	1.41	1.42	1.42	1.41	1.42
Cap. (AH)	15.0	15.0									15.0	14.5	14.0	14.5							15.25	14.5						
Vi	1.41	1.41	1.38	1.39	1.38	1.39	1.39	1.39	1.39	1.38	1.39	1.39	1.42	1.44	1.43	1.40	1.40	1.39	1.40	1.38	1.39	1.39	1.38	1.37	1.38	1.38	1.38	1.37
V Max	1.44	1.43	1.40	1.41	1.41	1.41	1.41	1.41	1.41	1.40	1.43	1.42	1.44	1.44	1.43	1.42	1.41	1.40	1.41	1.41	1.43	1.43	1.39	1.40	1.40	1.39	1.40	1.40
Vi	1.38	1.39	1.38	1.39	1.38	1.39	1.40	1.39	1.39	1.38	1.36	1.37	1.38	1.37	1.35	1.38	1.38	1.38	1.37	1.37	1.37	1.38	1.39	1.36	1.38	1.36	1.39	1.36
V Max	1.42	1.42	1.39	1.39	1.39	1.39	1.40	1.39	1.39	1.38	1.41	1.41	1.42	1.42	1.38	1.39	1.39	1.38	1.38	1.38	1.41	1.41	1.39	1.38	1.38	1.38	1.39	1.38
Vi	1.35	1.36	1.37	1.36	1.37	1.37	1.38	1.37	1.37	1.37	1.34	1.36	1.38	1.36	1.36	1.37	1.36	1.37	1.34	1.35	1.35	1.37	1.38	1.37	1.37	1.35	1.35	1.37
V Max	1.41	1.41	1.37	1.37	1.37	1.37	1.38	1.37	1.38	1.37	1.41	1.41	1.41	1.41	1.37	1.37	1.37	1.37	1.37	1.37	1.41	1.41	1.38	1.37	1.37	1.36	1.36	1.37
	57	58	59	60																								
Vi	1.35	1.36	1.35	1.36																								
V Max	1.42	1.42	1.43	1.43																								
Cap. (AH)			15.0	15.25																								
Vi	1.39	1.39	1.41	1.40																								
V Max	1.40	1.41	1.43	1.42																								
Vi	1.39	1.40	1.38	1.37																								
V Max	1.39	1.40	1.41	1.41																								
Vi	1.37	1.39	1.38	1.37																								
V Max	1.37	1.39	1.41	1.41																								

Vi indicates discharge voltage after 30 seconds.

V Max indicates maximum voltage attained during discharge.

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